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OPERATION AND EMISSSION CHARACTERISTICS OF CHP UNITS, FUELLED WITH RAPESEED OIL

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ABSTRACT: Rapeseed oil fuelled CHP units have major environmental benefits. However, operation experiences vary widely in practice and emission characteristics are fairly unknown. Therefore, within a research work, three CHP units were investigated for almost two years. Beneath technical features of the plants, fuel and engine oil quality, operation parameters, malfunctions, service and repair works as well as exhaust gas emissions were ascertained. The investigated plants show big differences in technical features. Problems occurred mostly within the fuel system, either due to insufficient rapeseed oil quality (e.g. high contamination, pre-aged oil) or due to unsuitable materials and components, like pumps and filters. Exhaust gas components NO_x and CO mostly meet the recommended orientation values. Limiting values, valid for bigger CHP units are also met for CO, when oxidative catalytic converters are used. However, to reach the aimed emission level for particulate matter, effective particle reduction systems (e.g. particle filters) are necessary.

Keywords: rapeseedoil, combined heat and power generation (CHP), operating experience

1 INTRODUCTION

Vegetable oil fuelled CHP units have major environmental benefits. Additionally to high efficiency of energetic conversion, which is achieved by combined heat and power generation (CHP), the utilization of vegetable oil fuels saves fossil resources and helps to protect the climate. Moreover, vegetable oils have hardly any impacts on soil and waters, due to their high biodegradability and low ecotoxicity. Thus, the use of vegetable oil should preferably focus on environmental sensitive areas, like alpine regions or water protection areas. Besides that, in rural areas, where vegetable oil is produced and used regionally, benefits are big due to low transportation efforts and positive effects on regional development. The Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG), which guarantees feed-in tariffs - paid by the grid operators - for electricity, derived from renewable energy sources, the declining reserves of mineral oil as well as an increasing sense of environmental responsibility of people are reasons, why the demand for small scale CHP units is growing permanently in Germany.

2 PROBLEM AND PURPOSE

However, the experiences with rapeseed oil fuelled CHP units vary widely in practice. The whole range from plants with good operation reliability to plants with many malfunctions can be found in practice. For a reliable and environmental low impact operation, various aspects have to be considered, as there are: fuel quality, technical equipment, operation mode, facility maintenance and emissions. Thus, it was the purpose of a research work, supported by the Bavarian State Ministry for Regional Development and Environmental Affairs, to ascertain relevant operation and emission characteristics of CHP-plants, that are used in practice, for a technical and an emission referred assessment [2]. Furthermore, experiences, which were made during the project, are combined in a guideline for the use of vegetable oil fuels in CHP-plants [3].

3 APPROACH

Three different types of rape seed oil fuelled CHP units of different power classes (8 kW_{el} (Figure 1), 60 kW_{el}, 110 kW_{el}) and manufacturers have been investigated for almost two years. Besides the monitoring of fuel and engine oil quality, malfunctions as well as service and repair works, also numerous important operation parameters like temperatures, pressures and flow rates of fuel, cooling water and exhaust gas have been recorded continually for weak-point analysis. Beyond that, exhaust gas emission were determined by recurrent measurements of CO_2, CO, NO_x, C_nH_m and particulate matter.

4 RESULTS

The three investigated CHP-units show big differences in technical features. Besides the different types of rapeseed oil fuelled engines, also big differences in the periphery (e.g. fuel system, exhaust gas cleaning technologie) were obvious. Also the daily and total operating hours varied widely between the three CHP units (Table 1).

Figure 1: Rapeseed oil fuelled CHP-Unit 1

Table1: Characteristics of the Investigated CHP Units

Characteristics	CHP Unit 1	CHP Unit 2	CHP Unit 3
Electric power	8 kW_{el}	60 kW_{el}	110 kW_{el}
Heating power	15 kW_{th}	90 kW_{th}	110 kW_{th}
Operation start	03/1999	06/1997	05/1996
Op.hrs 27/07/99	314	4 759	2 690
Op.hrs 14/12/00	5 165	10 277	3 290
Combustion	Swirl chamber	Direct injection	Direct injection
Displacement [l]	1,7	5,9	11,8
No. of cylinders	3	4	6
Heat exchangers	Generator Cooling water Exhaust gas	Generator Cooling water Exhaust gas	Charge Air Cooling oil Exhaust gas
Fuel preheating	None	In storage tank	In flow pipe
Fuel pump	Electric drive	Mechanical drive	Electric drive
Fuel pipes	Steel pipes	Copper pipes	Steel pipes NBR-hoses
Exhaust gas cleaning devices	Oxidation catalyst	Oxidation catalyst Simple soot trap	Oxidation catalyst Particle filter

4.1 Operation Characteristics – Weak Point Analysis

Operational malfunctions occurred mainly within the fuel system. Deficiencies as high particulate matter of the rapeseed oil or contamination - with for example tank residues - were reasons for several operation interruptions, partly requiring extensive maintenance. Besides frequently blocked fuel filters at one CHP unit, in another case once even the whole fuel system including the fuel and the injection pump had to be renewed. By using rapeseed oil in compliance with the "Quality Standard for Rapeseed Oil as a Fuel (RK-Qualitätsstandard 05/2000)" [1], which comprises important fuel quality requirements of rapeseed oil, operational interruptions, due to blocked fuel flow can largely be prevented.

But not only contaminated rapeseed oil, also for the high viscosity of rapeseed oil unsuitable or wrong positioned fuel pumps, the use of materials that accelerate oil aging (e.g. copper) or already spoiled oil, as it can happen in heated storage tanks, can cause problems in the fuel system. However, cool, dark and clean storage conditions minimize risks of oxidation and polymerisation of the fuel and help to secure fuel flow.

Due to the fact, that - in comparison to diesel fuel - rapeseed oil has a higher viscosity and tendency to build up gummy residues as well as due to higher injection pressures, the whole injection system is exposed to a higher load. This is why fuel pumps, injection pumps and injection nozzles need to be of high quality, not reaching their operational limit. Moreover, rapeseed oil with a high oxidation stability, low acid number and low water content minder the risk of early wear and corrosion of the engine and fuel system components.

Typical for vegetable oil engines are higher combustion temperatures. Thus, an efficient cooling of the engine is required to avoid severe engine damage due to overheating. A powerful ventilating system, clean surfaces of heat exchangers and enough cooling medium in the cooling system are conducive for good operation reliability. As many other engine powered CHP plants, vegetable oil fuelled CHP units require some effort for control and maintenance. Despite of the installed automatic control systems, that turn off the engine in cases of critical operation conditions, they cannot substitute regular inspections of qualified attendants. For successful operation of rapeseed oil fuelled CHP units competent and engaged personnel is essential to identify operational failure early and - if necessary - to take remedial measures.

4.2 Emission Characteristics

Despite environmental advantages of rapeseed oil fuel as mentioned above, harmful exhaust gas emissions need to be considered. Small CHP units with fuel inputs of less than 1 MW, which relates to about 400 kW_{el} are not subject to authorization. This is why emission limit values are not valid for the three investigated plants. Nevertheless for better interpretation, the concentrations of the emission components measured, are compared with limiting values, valid for plants, that are subject to authorization, and with orientation values for smaller plants, recommended by the department for air quality control and management.

All three CHP units show mean values for carbon monoxide emissions between 20 and 300 mg/m³ (referred to dry exhaust gas at standard conditions: 1013 hPa, 0 °C and 5 % O_2). Thus, all investigated CHP units easily fulfill the orientation value and also the limiting value, valid for bigger plants (Figure 2). Module 2 of CHP unit 3 was noticed to have the by far highest CO-emissions at the first two measuring days. Therefore, the reason can be a defective particle filter, which caused a permanently increased exhaust back pressure or an efficiency loss of the oxidative catalytic converter. After removal of the particle filter and change of the oxidation catalyst, CO emissions decreased on less than one third (see 17.10.00, Figure 2). The throughout very low CO emissions in the exhaust gas of all three CHP units can be attributed to the application of oxidation catalysts, whereby converting rates from 70 – 90 % can be achieved.

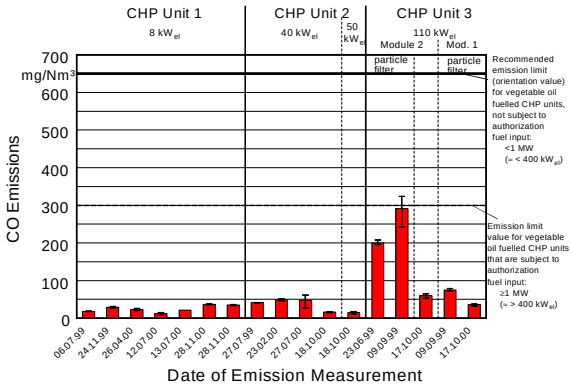

Figure 2: CO-Emissions of Rapeseed Oil Fuelled CHP Units (all with oxidation catalysts), referred to 5 % O_2

Within the measured nitrogene oxides emissions a difference in combustion type of the engines is obvious. For the swirl chamber engine of CHP unit 1 the concentration of NO_x is about 2000 mg/m³, whereas for the direct injection engines of unit 2 and 3 concentrations from 2200 to 3600 mg/m³ were measured (Figure 3). The recommended value of 3000 mg/m³ for CHP unit 1 and 2 can mostly be met. The measured NO_x emissions for unit

3 are slightly higher than the recommended value of 2500 mg/m³. Improved engine adjustment or exhaust recirculation might reduce NO_x emissions. Hence orientation values seem to be obtainable, whilst the limiting value of 1000 mg/m³ (valid for bigger plants) could only be reached, when catalyst technologies for NO_x reduction are applied.

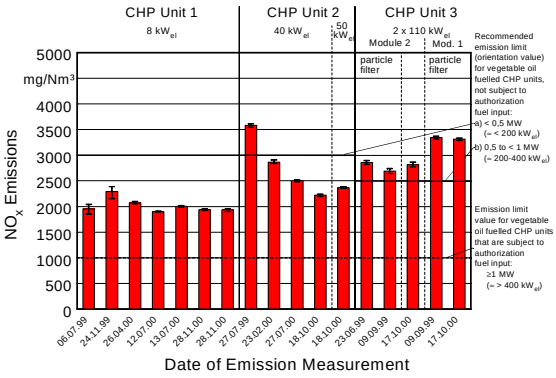

Figure 3: NO_x-Emissions of Rapeseed Oil Fuelled CHP Units, referred to 5 % O_2

At present a high importance is attached to particle emissions. Therefore the recommended limiting value is fixed at 20 mg/m³, valid also for smaller CHP units, that are not subject to authorization. For particle mass reduction, particle filters are very effective, as Figure 4 shows. With a mean value of 3 mg/m³ the particle mass emissions of CHP unit 3 (with particle filter) are significantly less than for unit 1 and 2 as well as for module 2 of unit 3 on the 17.10.00, all without particle filters. Here particle masses between 60 and 170 mg/m³ were measured. Though the particle filter of module 2 from CHP unit 3 was noticed to be highly susceptible to malfunction. Melted filter conduits, apparently caused by catalytic effects of accumulated not burnable fuel derived ashes, increased exhaust pressure and temperature. Both has to be avoided, in order not to affect engine durability.

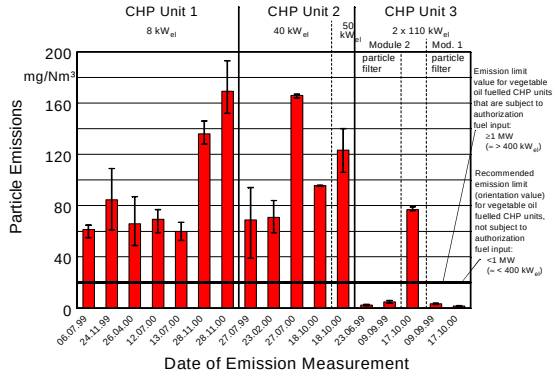

Figure 4: Particle Mass-Emissions of Rapeseed Oil Fuelled CHP Units, referred to 5 % O_2

5 CONCLUSIONS

Operation interruptions of the investigated rapeseed oil fuelled CHP units mainly occur due to problems, concerning the fuel flow. With fuel of low contamination and by using selected plant components, that are suitable for rapeseed oil, fuel flow is mostly guaranteed. Cold, dark and clean storage conditions plus appropriate tanks and pipes minder fuel polymerisation and formation of residues. Moreover, efficient engine cooling and prevention of excessive fuel entry into the engine oil help to avoid severe engine damage.

Although there are no emission limits for small CHP-plants at present, the investigated plants widely fulfill the recommended emission values of carbon monoxide (CO) and nitrogene oxides (NO_x). In order to reduce particle emissions particle filters are very effective, but need to be tested for their long term operability.

A reliable and environmentally low impact operation of rapeseed oil fuelled CHP units is possible, when fuel properties meet the demanded quality standard, when rapeseed oil proved components are used, maintenance is professional and emission reduction technologies are effective.

Focusing on the major environmental benefits, on the big differences in operational interruptions and emission levels of the investigated plants going along with increasing demands on reliability and emission control, the potential for optimising rapeseed oil fuelled CHP-units should be used.

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